level is increased at step **310** by sending a pulse to the actuator **206**. If the event of exiting the feature is detected at step **312**, the friction is decreased at step **304** by resetting the device with a negative pulse sufficient to reduce the friction below the nominal level, and then by bringing the friction back to the nominal level with a positive pulse of the desired magnitude. The process continues while the user is utilizing the address book mode. In this manner, the user is able to quickly scroll through a long list of names and addresses and is also able to precisely place a cursor or other indicator on an individual entry in an address book list.

FIGS. **4** and **5** are schematic diagrams illustrating a programmable surface feel in one embodiment of the present invention. Such an embodiment is capable of providing programmable surface feel in various manipulanda, including, for example, to a push button or other device designed to engage contact with a user's skin during operation.

The button **602** comprises a surface **604**. The surface **604** has an array of holes matching a plurality of teeth of an element **614** which can have two stable configurations, one in which the teeth are protruding as in FIG. **4** and the other in which the teeth are recessed as in FIG. **5**. The switch from one configuration to the other is accomplished by activating one of the solenoid coils **606** or **608** acting in the iron core **610**. An elastic membrane **612** is use to maintain the element **614** in one of the two stable configurations.

FIGS. **6** and **7** are schematic diagrams illustrating a programmable surface feel in another embodiment of the present invention. In the embodiment shown, a button **402** has a surface **404**. The surface **404** of the button **402** has an array of holes, including hole **406**. Located beneath the button surface **404** is an element **410** including a plurality of pins corresponding to the holes in the surface **404**. A slider **412**, which is activated by a solenoid **414**, has two stable positions. The left position illustrated in FIG. **6** allows the array of pins to move freely with the surface of the button **402**. The button surface **404** feels smooth when depressing the button **402**. When the slider **412** is in the position illustrated by FIG. **7**, the button surface **404** feels rough because the projects extend beyond the surface. In another embodiment, an actuator shifts the array of pins sideways with respect to the surface rather than indenting the skin. This can easily be accomplished by selectively engaging one or several cams as in the knob example above.

In one embodiment utilizing holes in the surface of a manipulandum, a membrane (not shown) is positioned above-the pins. The membrane allows a user to feel the pins and prevents dirt, dust, or other foreign matter from entering the mechanism an interfering with movement of the pins.

FIG. **8** is a flowchart illustrating a process for controlling the operation of the actuator shown in FIGS. **6** and **7** in one embodiment of the present invention. When a device changes state, this state is sent by a signal to the programmable button. For example, if a processor determines via a sensor signal that a device is turned off, the processor sends a signal to the actuator (**414**) to retract the pins (**410**). When the user places a finger on the membrane above the button (**402**) with the pins (**410**) retracted, the user can determine that the device is off without looking at the button or any other indicator.

When the user depresses the button (**402**), turning on the device, the processor receives a device status change signal indicating that the device is now on **508**. The processor determines whether the device is now on or off by evaluating a data value associated with the signal **510**. For example a value of "1" may indicate that the device is on; a value of "0" may indicate that the device is off. If the device is now off, the processor sends a signal to the actuator (**414**) to extend the pins (**410**) **512**. If the device is now on, the processor sends a signal to the actuator (**414**) to retract the pins (**410**) **514**. The process then ends **516**. Again, solely by touching the button (**402**), the user is able to determine the state of whatever system or device the button (**402**) controls.

For example, in one embodiment, a button with an actuator according to the present invention controls the rear defroster of an automobile. Conventional buttons for controlling the rear defroster of an automobile often comprise an indicator light, which is illuminated when the defroster is on. With defrosters that turn themselves off after a time period, the user must look at the indicator light to determine whether or not the defroster is on. A button according to the present invention allows the user to determine whether or not the rear defroster is on simply by touching the control button. If the defroster is on, the pins are extended, and the user is able to feel the pins through the surface membrane of the switch.

The embodiment shown in FIGS. **4**, **5**, **6**, and **7** is merely exemplary of how surfaces may be altered by embodiments of the present invention. Embodiments of the present invention may provide numerous other surface alterations as well.

An embodiment of the present invention may be advantageously implemented in applications where low power consumption is critical, such as in a remote control. In one embodiment of the present invention in a remote control, a knob allows the user to control multiple functions, such as volume, fast-forward/rewind (shuttle) and frame-by-frame picture (jog) control. When the user selects the volume control mode, the actuator engages a profile that allows the knob to move freely between to stops, a minimum and a maximum. When the user selects the jog control mode, the actuator engages a profile that allows the knob to move three hundred and sixty degrees through a series of equidistant detents.

One embodiment of the present invention comprises a toggle switch connected to a controllable profile element, which is further connected to an actuator. The toggle switch is able to move in one plane between two stops. In a first profile, the toggle switch is able to move throughout its range of motion with no detents. In a second profile, the toggle switch comprises a detent at or near one end of its range of motion and at or near the second end of its range of motion, operating like a conventional two-way light switch. In a third profile, the toggle switch comprises a third detent at approximately the mid-point of its range of motion. In one such embodiment, the mid-point comprises a neutral position.

Embodiments of the present invention may be pre-programmed. For example in one embodiment, a knob according to the present invention comprises three programmable profiles. The manufacturer of the knob delivers a shipment of these knobs to an automobile manufacturer. The automobile manufacturer uses the same type of knob to perform many different functions, requiring distinct profiles for each or between many of these distinct functions. The manufacturer is able to program the knob to provide a specific profile upon installation of the knob by applying power to the actuator. The knob retains this profile unless or until the profile is later changed. In the meantime, the device requires no power to impart the desired haptic effect.

Embodiments of the present invention may be used alone or in combination with other low-power haptic feedback devices, conventional mechanical devices, and active and passive/resistive haptic feedback devices. For example, a knob having various low-power detent effects may also be in communication with a vibratactile actuator, for example, an eccentric rotating mass (ERM) actuator, which imparts a vibration on the knob under certain conditions.